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Macroeconomic Evaluation of Climate Change Model (MECC-Model): The Case Study of China

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THE MACROECONOMICS EVALUATION OF CLIMATE CHANGE MODEL (MECC-MODEL): THE CASE STUDY OF CHINA

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Abstract

Global climate change has a potentially large impact on economic growth but measuring their economic impact is subject to a great deal of uncertainty. The central objective of our paper is to set forth a model – the macroeconomics evaluation of climate change (MECC) model – to evaluate the impact of climate change on GNP growth. The model is based on five basic indicators – (i) the climate change growth rates ($\boldsymbol{\alpha_i}$); (ii) the national climate change vulnerability rate ($\boldsymbol{\Omega_T}$); (iii) the climate change magnitude rate ($\boldsymbol{\Pi}$); (iv) the economic desgrowth rate ($\boldsymbol{\delta}$); (v) and the CC-Surface. In addition, we apply the MECC Model to the case of China to evaluate its impact on the Chinese economy.

1. Introduction

Initially, this paper aims to study the effect of climate change on the GDP. According to this research paper the climate change can be considered a natural disorder event (cause) that is generated by natural evolutionary reasons or the high demand of natural resources in the production and consumption of goods and services that can generate irregular climate change imbalances (effect) in different environmental habitats systems respectively (Ruiz Estrada, 2013). Hence, any climate change can have a potentially large effect on economic growth but measuring their economic impact is subject to a great deal of uncertainty in the climate change (Loayza, Olaberria, Rigolini, Christiaensen, 2009). They impose both direct and indirect costs, and those costs change and evolve over time. The climate change adversely affects the economic activity in the short run through a number of channels. For example, different parts of China floods or drought severely curtailed agriculture sector output by destroying plantations, forestry, fisheries, cattle, water resources, transportation systems, telecommunications systems, private and social infrastructure, and housing. Beyond the very short term, however, the negative economic impact of climate change tends to fade. For example, in the Central South China (Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan) and Southwest (Chongqing, Sichuan, Guizhou, Yunnan, Tibet) we can observe that between 1992 and 2012 huge impact of climate change disorders that was generated a large amount of material and human losses, the government's reconstruction spending spearheaded a robust recovery in private investment and consumption. As a result, macroeconomic indicators recovered slowly after an initial drop. Given the potentially large effects of climate change on economic growth, it is important for policymakers to have reasonably accurate estimates of those effects (Kunreuther and Rose, 2004). However, this is difficult given the high uncertainty surrounding the measurement of those effects. The motivation for this paper comes from the large numbers of climate change which seem to be inflicting damage on the world economy with growing frequency. Developing countries in particular are more vulnerable to climate change due to high pollution levels and non-controlled natural resources depredation. Developing Asia in particular accounted for 55% of global fatalities and 30% of all persons affected globally by climate change between 2000 and 2012. According to Table 1 shows the fatalities and estimated damages from various types of climate change in developing Asia between 2000 and 2012. The estimated damages imply a sizable negative economic impact on the region.

[INSERT TABLE 1]

The central objective of our paper is to set forth a model – the macroeconomics evaluation of climate change (MECC) model – to evaluate the impact of climate change on GNP growth. The model is based on five basic indicators - (i) the climate change growth rates (α_i); (ii) the national climate change vulnerability rate ($\boldsymbol{\Omega_T}$); (iii) the climate change magnitude rate ($\boldsymbol{\Pi}$); (iv) the economic desgrowth rate ($\boldsymbol{\delta}$); (v) and the CC-Surface. Furthermore, this model is also based on elements from an alternative mathematical approach analysis framework from a multidimensional perspective. We look at different types of climate change that occurred around the world between 1992 and 2012. To illustrate and illuminate the MECC model, we apply it to assess the economic impact of China. For comparative purposes, we also apply the model to an earlier climate change in different Chinese regions. We hope that the MECC model will contribute toward a more systematic and accurate measurement of the economic impact of climate change.

2. Economic Modeling in the Evaluation of Climate change

2.1. Classic Economic Modeling in the Evaluation of Climate change

Firstly, this paper studies the origins of the economics of climate change. We have as a foregoing the first two documents was published by William Cline (1992) and John Reilly & Chris Thomas (1993) that are entitled "The Economic of Global Warning" and "Toward Economic Evaluation of Climate Change Impacts: A Review and Evaluation of Studies of the Impact of Climate Change" respectively. Hence, these two papers give us the first economic analysis about the impact of climate change from a microeconomic and macroeconomic perspective. Moreover, we wish to analyze another economic novel by using the book wrote by Jonathan Harris and Brian Roach that was published in the year 2002. This other book did a great analysis about causes and consequences of climate change from an economic perspective. According to Jonathan Harris and Brian Roach (2002) arguments on its book, they said: "Concern has grown in recent years over the issue of global climate change. The problem, frequently called global warming, is more accurately referred to as global climate change. A basic warming effect will produce complex effects on climate patterns -- with warming in some areas, cooling in others, and increased climate variability. In terms of economic analysis, greenhouse gas emissions, which cause planetary warming, represent both environmental externalities and overuse of a common property resource. If indeed the effects of climate change are likely to be severe, it is in everyone's interest to lower their emissions for the common good. But where no agreement or rules on emissions exist, no individual firm, city, or nation will choose to bear the economic brunt of being the first to reduce its emissions. In this situation, only a strong international agreement binding nations to act for the common good can prevent serious environmental consequences."

Therefore, we are sharing common points about Jonathan Harris and Brian Roach arguments on its great book. Especially, we are fully agrees that in the case of policies and implications this book show some crucial points about climate change. But we cannot deny that the economic modeling in the book entitled “The Economic of Global Warning” by William Cline (1992) and the working paper entitled “Toward Economic Evaluation of Climate Change Impacts: A Review and Evaluation of Studies of the Impact of Climate Change” by John Reilly and Chris Thomas (1993) continues until our days as the cornerstones in the study of economics of climate change. In our personal point of view the major contribution of these two papers is the analysis of a short and long term recovery model that makes reference about the climate stabilization process involving the community back to the past economic level. In fact, all these three authors define climate stabilization as “this should be the goal, rather than economic optimization of costs and benefits. Stabilizing greenhouse gas emissions is not sufficient, since at the current rate of emissions carbon dioxide and other greenhouse gases will continue to accumulate in the atmosphere. Stabilizing the accumulations of greenhouse gases will require a significant cut below present emission levels.” It is important to mention that the short and long term recovery model formulation is based on the use of the cost benefit by using the equilibrium general circulation model (GCM) runs at 2xC02 give different levels of C° by Manabe and Kirk (1969) to estimate the annual damages of any economy from global climate change.

Another two interesting papers need to be mentioned in our research is about "CETA: A Model for Carbon Emissions Trajectory Assessment" by Peck and Teisberg (1992) and "The Economics of Controlling Stock Pollutants: An Efficient Strategy for Greenhouse Gases" by Ita and Mendelsohn (1992). According to Reilly and Thomas analysis on these two papers, they said: “These two models they have developed provide more applicability in representing damages as non-linearly related to a single climate change indicator and they study the implications of damages that are linear, quadratic, and cubic in the climate variable. Peck and Teisberg also evaluate the case where damages are related to the rate of change rather than the level of climate change. If damages are related to the rate of climate change, the economically optimal level of control is less. If climate stops changing at any level, no more damages occur. In contrast, if the level of change matters, then the flow of damages accruing during each period continues to accumulate even if climate change is halted. To stop the flow of damages, climate change must actually be reversed. Viewing damages as related to the rate of change is consistent with a view that damages are due largely to adjustment, where slow climate change may have negligible effects even if the rate persists over many years. In considering these different possibilities, Peck and Teisberg do not provide evidence for any particular damage function relationship. Their work only illustrates the importance of further research to clarify how damages can best be represented." In our opinion, building a model of this magnitude in the year 1992 was amazing. If we observe the limitation of database confined to simple observations, it is clear that all these authors were mentioned they are great, with its futuristic view about climate change and its impacts.

2.2. Modern Economic Modeling in the Evaluation of Climate change

Since the 1990's, the economics of climate change have experienced a deep transformation (in form and content) and faster research expansion using sophisticated analytical tools to evaluate the climate change effects such as the implementation of more modern statistical, mathematical and econometric modeling through the uses of advanced software (modern econometrics software programs) and hardware (computers with fast speed and high memory storage). Hence, we can mention some interesting research works about economics of climate change such as reconciling the science and economics of climate change by Eban Goodstein (2011); the economics of decarbonizing the energy system—results and insights from the RECIPE model intercomparison by Gunnar Luderer, Valentina Bosetti, Jack Steckel, and Henri Waisman (2012); on the economics of decarbonization in an imperfect world by Ottmar Edenhofer by Carlo Carraro and Jean-Charles Hourcade (2012); a problematic social science approach to the study of climate science by Nils Roll-Hansen (2013); on the economics of decarbonization in an imperfect world by Ottmar Edenhofer, Carlo Carraro, and Jean-Charles Hourcade (2012); the economics of climate change: implications for federal policy by Goshay (1970); the Economic of climate change: concepts and methods by Stephane Hallegate and Valentin Przyluski (2010). Some of these research works are using some basic ideas from the original research work by William Cline (1992) and John Reilly and Chris Thomas (1993). Additionally, we can observe that the major part of these research works is focused on climate change damage that affected consumption and production directly. According to this research, the most common model employed to study economic of climate change is the benefit cost model. Peck and Teisberg (1992) observe that the benefit cost model can only show the basic interdependency that exists among different sectors. At the same time, the benefit cost model leaves out explicit resources constraints, import substitution and price change behavior. Therefore, many economists specialized on the study of climate change. Subsequently, they prefer to use the computable general equilibrium (CGE) model rather than the benefit cost model, because the CGE-model is more flexible to capture more variables in the process of economic modeling. Moreover, we need to mention another theoretical framework that is widely used in the study of economics of climate change which is the RECIPE model (Gunnar Luderer, Valentina Bosetti, Jack Steckel, and Henri Waisman, 2012). The RECIPE model is designed to study different macro-economic effects of climate change simultaneously. It is employs a group of coefficients that estimate the impact of the climate change by evaluating the feasibility of different possible public policies to manage climate change under different magnitudes.

Finally, the econometric models used to analyze climate change show some deficiencies in their incorporation of non economics variables and technical indicators into the analysis of climate change effects as a whole. Therefore, we need to bring into the study of economics of climate change, a new dynamicity and complexity through innovative mathematical and graphical approaches to have a better understanding the behavior of climate change. The idea to build the MECC model is to innovatively access the impacts and consequences of a climate change. In fact, the MECC model tries to evaluate higher order effects of uncertainty after a climate change which needs beyond to be incorporated into the analysis of economic impacts of the climate change. We try to go using the MECC model. Our main objective is to account for this uncertainty and behavioral change from a multidimensional perspective (mathematical and graphically) within the framework of a dynamic imbalanced state (DIS) (Ruiz Estrada and Yap, 2012) and the Omnia Mobilis assumption (Ruiz Estrada, 2011). The idea is to move on from the classical economic modeling: linear and non-linear models (for example benefit cost model, CGE model, RECIPE model, and other models) to new economic mathematical modeling and mapping of climate change (ex-ante –before the climate change- and ex-post –after the climate change-) by using high resolution of multidimensional graphs.

3. The Macroeconomics Evaluation of Climate Change (MECC) Model

The macroeconomics evaluation of climate change (MECC) model assumes that any country is vulnerable to climate change anytime and anywhere. Additionally, each climate change has its own level of potential damage and impact on the final GNP for any country. Hence, our world is in a constant dynamic imbalanced state. This means that, at anytime and anywhere, that exist the possibility of a climate change and that it can generate different magnitudes of climate change levels. When this model refers to a climate change, we are referring to any event beyond human control that can generate massive destruction anytime, anywhere, without any advance warning. The quantification and monitoring of climate change is inherently difficult, and we cannot evaluate and predict them with any degree of accuracy, but we can compute series of climate change within a fixed period of time (per year or decades). In addition, this MECC model is useful for demonstrating how the GNP growth rate is directly connected to the presences of climate change.

In the context of the MECC model, we would like to propose five new indicators - the climate change growth rates ($\boldsymbol{\alpha_i}$), the national climate change vulnerability rate ($\boldsymbol{\Omega_T}$), the climate change magnitude rate ($\boldsymbol{\Pi}$) the economic desgrowth rate ($\boldsymbol{\delta}$) and the CC-Surface. These five indicators aim to simultaneously show the different levels of vulnerability and devastation arising from different climate change. These five indicators are determined by the collection of historical data of different climate change that have been impacted in any country whereby climate change are defined according to certain intervals of time and the magnitude of climate change. According to our model the analysis of any climate change from an economic point of view must take into account the production reduction (national output) and human capital mobility (labor) simultaneously. In this part of our model, we introduce a new concept is called "economic desgrowth (δ)**"** (Ruiz Estrada, 2010). The economic desgrowth rate (δ) is defined as a leakage of economic growth due to any climate change. The main objective of the economic desgrowth rate ($\boldsymbol{\delta}$) is to determine the ultimate impact of any climate change on the final GNP growth rate behavior over a certain period of time. The basic data used by the macroeconomics evaluation of climate change model (MECC model) is based on the use of sixteen different possible climate change events. These include mean temperature; temperature extremes; mean precipitation; precipitation extremes; snow and ice; carbon cycle; ocean acidification; sea level; El Niño; monsoons; sea level pressure; radiative forcing; tropical cyclones; hailstorms; sandstorm; hurricanes and typhoons.

3.1.1. The National Climate Change Vulnerability Rate (Ω_T)

According to the MECC model, we assume an irregular oscillation into different climate change events all the time. We do so by applying the climate change growth rates (**αi**) is equal to the total sum of the same type of climate change event in the present year ($\Sigma\lambda_o$) minus the total sum of the same type of climate change event at the past 10 years ($\Sigma\lambda_{n-1}$) divided by the total sum of the same type of climate change event at the past 10 years ($\Sigma\lambda_{n-1}$) (see Expression 1).

$$\alpha_i = \Sigma\lambda_o - \Sigma\lambda_{n-1}/\Sigma\lambda_{n-1} \qquad (1)$$

It means that our world is going to be in a permanent dynamic imbalanced state under high risk of having a climate change event at anytime. The MECC model allows for different magnitudes of climate change. Therefore, we have different climate change events growth rates (α_i) as described in expression 2. Therefore, we assume that the national climate change vulnerability rate (Ω_T) is directly connected to time (T_j). At the same time, T_j is affected directly by different climate change growth rates (α_i). In our case "**j**" is a specific period of time and "**i**" represents the type of climate change that according to our classification we are using sixteen different types of climate change. Hence, the national climate change vulnerability rate (Ω_T) includes a total of sixteen possible climate change events that are as follows: mean temperature (α_1); temperature extremes (α_2); mean precipitation (α_3); precipitation extremes (α_4); snow and ice (α_5); carbon cycle (α_6); ocean acidification (α_7); sea level (α_8); El Niño (α_9); monsoons (α_{10}); sea level pressure (α_{11}); radiative forcing (α_{12}); tropical cyclones (α_{13}); hailstorms (α_{14});

sandstorm ($\boldsymbol{\alpha}_{15}$); hurricanes and typhoons ($\boldsymbol{\alpha}_{16}$) respectively. Each global climate change has its magnitude of intensity according to the geographically position and environmental problems. We assume that if any climate change event is distant follows each other then it is not possible to be predicted with accuracy as in expression 4. Hence, we can calculate the national climate change vulnerability rate ($\boldsymbol{\Omega}_\mathbf{T}$) is equal to the total sum of all $\boldsymbol{\alpha}_\mathbf{i}$ that is divided by the total of climate change in analysis ($\mathbf{i}_{\mathbf{total}}$) (see Expression 3). In our case we are using sixteen different climate change variables in this research.

$$\boldsymbol{\Omega}_\mathbf{T} = (\Sigma\alpha_i)/i_{total} \;\; \in [0 < \Sigma\alpha_i < 1] \quad i_{total}=16 \tag{2}$$

$$\boldsymbol{\Omega}_\mathbf{T}\mathbf{e} = \mathrm{Ln}[(\alpha_i)_{Tj} - (\alpha_i)_{Tj-1}]/(\alpha_i)_{Tj}] \qquad \forall \; \boldsymbol{\Omega}_\mathbf{T}\mathbf{e} \neq 0 \tag{3}$$

$$\boldsymbol{\Omega}_\mathbf{T}\mathbf{p} = \mathrm{Ln}[(\alpha i_{max})_{Tj}] - [(\alpha i_{min})_{Tj})] \quad 0 > \alpha i_{max} \leq 1 \text{ or } 0 \geq \alpha i_{min} < 1 \tag{4}$$

$$\boldsymbol{\Omega}_\mathbf{T}\mathbf{e} \ddagger \boldsymbol{\Omega}_\mathbf{T}\mathbf{p} \tag{5}$$

In expression 3 and 4 shows the effective national climate change vulnerability rate ($\boldsymbol{\Omega}_\mathbf{T}\mathbf{e}$) and the potential national climate change vulnerability rate ($\boldsymbol{\Omega}_\mathbf{T}\mathbf{p}$). The effective national climate change vulnerability rate ($\boldsymbol{\Omega}_\mathbf{T}\mathbf{p}$) is based on compare the past and present climate change events growth rates. We assume that the present national climate change vulnerability rate $\boldsymbol{\Omega}_\mathbf{T}$ cannot be equal to zero (see Expression 3). However, the potential national climate change vulnerability rate ($\boldsymbol{\Omega}_\mathbf{T}\mathbf{p}$) is based on the uses of a maximal and minimal climate change events growth rate into a determinate period of time ($\mathbf{T}_\mathbf{j}$) (see Expression 4). Additionally, we need to assume that the potential national climate change vulnerability rate ($\boldsymbol{\Omega}_\mathbf{T}\mathbf{p}$) exist a random database which makes it possible for the MECC model to analyze unexpected results from different climate change events which cannot be predicted and monitored with the traditional methods of linear and non-liner mathematical modeling. Hence, the effective climate change events growth rate is identified in Expression 3. Finally, our identity about the potential climate change event growth rate cannot be equal to the effective climate change events growth rate in the short run or long run (see Expression 5). This is because we assume at the very outset that our world is in a dynamic imbalanced state.

Thus $\mathbf{\Omega_T}$ calculation is possible to be observed in table 3 to different countries by using different α_i and a single Ω_T. The evaluation of the national climate change vulnerability rate ($\mathbf{\Omega_T}$) is applied three different levels of vulnerability (see Expression 6)

Level 1: High vulnerability (red color alert): 1 - 0.75

Level 2: Average vulnerability (yellow color alert): 0.74 – 0.34

Level 3: Low vulnerability (red color green): 0.33 – 0 (6)

[INSERT TABLE 3]

However, in Figure 2, it is possible to observe diminishing returns between the economic desgrowth rate ($\boldsymbol{\delta}$) and the national climate change vulnerability rate ($\mathbf{\Omega_T}$). We can have three possible scenarios of analysis in this relationship between the economic desgrowth rate ($\boldsymbol{\delta}$) and the national climate change vulnerability rate ($\mathbf{\Omega_T}$). First scenario, if the national climate change vulnerability rate ($\mathbf{\Omega_T}$) is very high then the economic desgrowth rate ($\boldsymbol{\delta}$) will be high. Second scenario, if the national climate change vulnerability rate ($\mathbf{\Omega_T}$) is very low then the economic desgrowth rate ($\boldsymbol{\delta}$) will be low (see Figure 1). Finally, we assume that never the national climate change vulnerability rate ($\mathbf{\Omega_T}$) can intercepts the economic desgrowth rate ($\boldsymbol{\delta}$), because we are using **"The Dynamic Imbalanced State (DIS)"**. The DIS never keeps static but constantly keeps changing. Hence, we suggest the application of the Omnia Mobilis assumption to keep the DIS in the long run. It changes according to change in the national climate change vulnerability rate ($\mathbf{\Omega_T}$).

[INSERT FIGURE 2]

3.2. The Climate Change Magnitude Rate (**Π**)

Basically, we are using two main variables to calculate the climate change magnitude rate (**Π**). The first main variable that is capital devastation (**Φk**), we compute capital devastation (**Φk**) by dividing the area of infrastructure destroyed by the climate change (km^2) by total infrastructure area (km^2) in the same geographical space. The second main variable is human capital devastation (**ΨL**). We compute human capital devastation (**ΨL**) by dividing the number of people killed by or missing due to climate change by the total population in the same geographical space. After calculating both main variables, we can then multiply the results to get our natural disaster magnitude rate (**Π**). In short, the climate change magnitude rate (**Π**) is equal to the product of the capital devastation (**Φk**) and the human capital devastation (**ΨL**). Finally, we generate the natural logarithm. To calculate the final climate change magnitude rate (**Π**) that is expressed in the expression 7.

$$\mathbf{\Pi} = f(\Phi k, \Psi L) = \text{Ln}\,[(\Phi k) \text{ x } (\Psi L)] \tag{7}$$

We decide to apply the product rule of differentiation in the expression 7 to obtain the first derivative test to find the relative maximum and minimum in the capital devastation (**Φk**) and capital devastation (Φk) (see Expression 8, 9, and 10).

$$\partial f/\partial(\Phi k) = \Phi'(k)\Psi L/\ \Phi(k)\ \Psi L \tag{8}$$

$$\partial f/\partial(\Psi L) = \Psi'(L)\Phi(k)/\ \Psi(L)\Phi(k) \tag{9}$$

$$\partial \Pi = \Phi'(k)\ \Psi(L) + \Phi(k)\ \Psi'(L) \tag{10}$$

Moreover, we can also observe that the climate change magnitude rate (Π) is directly proportional to the national climate change vulnerability rate ($\mathbf{\Omega_T}$). Refer to table 2 and figure 2 respectively.

[INSERT TABLE 2 AND FIGURE 2]

3.3. The Economic Desgrowth (δ)

We define economic desgrowth ($\boldsymbol{\delta}$) (Ruiz Estrada, 2010) as a macroeconomic indicator that show the final impact of any climate change on the GNP. We can say that the final GNP post-climate change effect is a function of the climate change magnitude rate ($\boldsymbol{\Pi}$) (see Expression 11). At the same time, the climate change magnitude rate ($\boldsymbol{\Pi}$) is directly dependent on the national climate change vulnerability rate ($\boldsymbol{\Omega_T}$) (see Expression 11) according to Figure 1 and 2. In expression 12 we calculate the preliminary GNP post-climate change effect ($\mathbf{Q}'$). Hence, the $\mathbf{Q}'$ is in function of $\boldsymbol{\Pi}$.

$$\boldsymbol{\Pi} = f(\boldsymbol{\Omega_T}) \qquad (11)$$

$$\mathbf{Q'} = f(\boldsymbol{\Pi}) \qquad (12)$$

Therefore, the economic desgrowth ($\boldsymbol{\delta}$) depends on these two functions in our model according to expression 13. (i.e. a function of a function). Therefore, the economic desgrowth rate ($\boldsymbol{\delta}$) can only get values between 0 and $-\infty$...

$$\boldsymbol{\delta} = f(\Pi(\Omega_T)) \qquad (13)$$

In the last instance, the final GNP preliminary climate change effect ($\mathbf{Q'}$) directly depends on the climate change magnitude rate ($\boldsymbol{\Pi}$) (see Expression 14).

$$\mathbf{Q'} = f(\Pi) \qquad (14)$$

Finally, the economic desgrowth rate ($\boldsymbol{\delta}$) is equal to the preliminary GNP post-climate change effect ($\mathbf{Q}'$) minus the final GNP pre-climate change effect ($\mathbf{Q_o}$) (see Expression 15).

$$\delta = Q^{'} - Q_o \qquad (15)$$

In figure 1 and 2 we can observe that exist a strong relationship between the economic desgrowth **($\boldsymbol{\delta}$)** and **$\boldsymbol{\Pi}$** and **$\boldsymbol{\Omega_T}$**. Basically, the empirical results show that if **$\boldsymbol{\Pi}$** and **$\boldsymbol{\Omega_T}$** are higher, then the economic desgrowth (**$\boldsymbol{\delta}$**) shows the same behavior. Our experiment is based on the uses of different rates from 0.00 to 0.99 in the case of **$\boldsymbol{\Omega_T}$**. The finals results calculated for the economic desgrowth rates (**$\boldsymbol{\delta}$**) show that when the **$\boldsymbol{\Pi}$** and **$\boldsymbol{\Omega_T}$** are high the effect on the economic desgrowth (**$\boldsymbol{\delta}$**) is magnified. Hence, the δ is directly proportional to **$\boldsymbol{\Pi}$** and **$\boldsymbol{\Omega_T}$** in the long run (see Table 2). Finally, we assume that the economic desgrowth (**$\boldsymbol{\delta}$**), **$\boldsymbol{\Pi}$**, and **$\boldsymbol{\Omega_T}$** are moving significantly together (see Expression 15 and 16). Always **$\boldsymbol{\delta}$** start from zero and keep negative values according to our model.

$$\uparrow\delta = f\uparrow\Pi\ (\uparrow\Omega_T) \qquad (15)$$

$$\downarrow\delta = f\downarrow\Pi\ (\downarrow\Omega_T) \qquad (16)$$

3.4. The Climate Change Surface (CC Surface)

The construction of the CC-Surface is based on the climate change growth rates (**$\boldsymbol{\Omega}$i**) results and the mega-surface coordinate space (see Expression 17 and Figure 3). The climate change vulnerability surface is a four by four matrix that contains the individual results of all sixteen variables (taken from Table 3). However, the sixteen variables are plotted in a four by four array with the vertical value on the CC-Surface. The idea is to produce a surface for a quick pictorial representation of the overall propensities for any one country. The underlying idea here is to use the results of sixteen variables in the climate change growth rates (**$\boldsymbol{\Omega}$i**) to build a symmetric surface. When the MD-coordinate system (**$\boldsymbol{\eta}$**) has strictly the same number of rows as the number of columns, then the climate change growth rates (**$\boldsymbol{\alpha}$i**) can always be perfectly symmetric.

$$\boldsymbol{\eta} = \begin{pmatrix} \alpha_1 & \alpha_5 & \alpha_9 & \alpha_{13} \\ \alpha_2 & \alpha_6 & \alpha_{10} & \alpha_{14} \\ \alpha_3 & \alpha_7 & \alpha_{11} & \alpha_{15} \\ \alpha_4 & \alpha_8 & \alpha_{12} & \alpha_{16} \end{pmatrix} \qquad \mathbf{(17)}$$

The final analysis of the CC-surface depends on any change that this surface can experience in a fixed period of time.

[INSERT FIGURE 3]

4. The Macroeconomics Evaluation of Climate Change Model (MECC Model): The Case Study of China

Applying the MECC-Model to the Chinese economy will give us a much better idea of how the model works. Before we do so, it is useful to have a look at general data about China such as the contribution of each region to the final GNP of China and the geographical distribution of Chinese agriculture production. In terms of the geographical distribution of Chinese GNP, we find that North China contributes around 12% of GNP. East China region contributes 34%, the highest share. The region with the less contribution to China's GNP is Northeast China region with 15%. Therefore, the major contributors to Chinese GNP are the Central South China and Southwest China regions' which collectively account for 39% of Chinese output. Finally, the region of Northeast region contribution is 15% to Chinese output (see Figure 5). Central South China and East China also account for about 57% of Chinese GNP output. Additionally, we are interested to identified the Chinese agriculture output by regions such as North China (12%), Northeast China (10%), East China (13%), Central South China (30%), and Southwest China (35%) respectively (see Figure 6)

[INSERT FIGURE 5 AND 6]

5. The Climate Change Growth Rates (α_i)

In this section, we first examine the natural disaster vulnerability propensity rate for countries around the world and then we take a closer look at China's natural disaster vulnerability propensity rate.

a. The World Wide Climate Change Growth Rates ($\boldsymbol{\alpha_i}$)

Table 3 shows the Climate Change growth rates ($\boldsymbol{\alpha_i}$) in 17 countries around the world. The 17 countries show a wide range of probability of climate change event based on their historical data. We use three different colors to classify countries according to their climate change growth rates ($\boldsymbol{\alpha_i}$). Firstly, the red color represents high vulnerability, the yellow color represents medium vulnerability and the green color represents low vulnerability. We can observe in Table 3 that the ten countries with the highest risk of climate change are China; U.S.; Australia; Taiwan; Chile; Guatemala. Figure 8 shows the climate change vulnerability surface for 5 countries – China, US, Malaysia, Guatemala and Bangladesh. Therefore, China is among the top ten countries with the highest climate change growth rates ($\boldsymbol{\alpha_i}$), to be more specific second highest according to the list. On the other hand, countries such as Panama, Iceland, Spain, and Israel have the lowest climate change growth rates ($\boldsymbol{\alpha_i}$). This means that according to historical data, they face lower risk of climate change than the other countries in our sample.

[INSERT TABLE 3 AND FIGURE 8]

b. The Chinese Climate Changes Vulnerability Rate (Ω_T): Max and Min

In the case of China, we find large differences between the maximum and minimum of the climate changes vulnerability rate ($\boldsymbol{\Omega_T}$). According to historical data of climate change, --- has the lowest vulnerability, with a $\boldsymbol{\Omega_{Tmin}}$ of only 0.15 and $\boldsymbol{\Omega_{Tmax}}$ of 0.25. In the rest of China, the climate change vulnerability propensity rates are higher. More specifically, vulnerability rate ranges from 0.45 to 0.95 in ---, from 0.35 to 0.95 in ---- region, and from 0.25 to 0.85 in ---- region. (see Table 4).

[INSERT FIGURE 4]

c. The Climate Change Magnitude Rate (Π)

In addition, we would like to compare the climate change magnitude rate (**Π**) between ---- China floods in the year 1931 and China floods in the year 2010. The paper estimates and compares the magnitude of the impact of that climate change on China. According to our results the floods devastation resulting from the China floods in the year 2010 ---- floods was quite limited at –11. But the devastation floods caused by the China floods in 1931 were much larger at -5 according to our computations below. In Figure 7, we can observe more clearly from a graphical perspective that the China floods in 1931 caused a much larger devastation several times than the --- China floods in 2010 China according to our model final results.

[INSERT FIGURE 7]

Climate change magnitude rate of China floods in the year 1931 ($\Pi_{1931)}$			**(Π)**
Φk			
20b	80b	0.25	
ΨL			
4M	60M	0.067	**-5**
Climate change magnitude rate of China floods in the year 2010 ($\Pi_{2010)}$			
Φk			
51b	375b	0.14	
ΨL			
5000	30M	0.000067	**-11**

d. The Economic Desgrowth (δ)

Finally, to measure the impact of the floods and temperature change on economic growth, we use the new concept of "economic desgrowth (**δ**)" introduced by Ruiz Estrada (2010). According to the concept of economic desgrowth, we try to discover possible leakages that can adversely affect GNP performance. Basically, this new concept assumes that in the process of the GNP formation, leakages may arise due to different factors, in our case climate change. According to our estimates, the economic desgrowth caused by the Central South China floods in year 1931 has an impact of -1.51 on China's economic desgrowth (δ). Our estimates indicate that the economic desgrowth caused by the Central South China floods of 2010 has been much larger, at -2.8 in 2010. Therefore, the economic desgrowth difference between the Central South China floods of 1992 and Central South China floods of 2010 is -1.29 according to our final result in Table 4.

[INSERT TABLE 3 AND FIGURE 8]

6. Concluding Observations and Policy Implications

Climate change can have a significant negative impact on economic performance but measuring this impact with any degree of certainty is inherently challenging. In this paper, we propose a new model for evaluating the impact of climate change on economic performance. The macroeconomics evaluation of climate change (MECC) model is based on three indicators - (i) the climate change growth rates ($\boldsymbol{\alpha_i}$); (ii) the national climate changes vulnerability rate ($\boldsymbol{\Omega_T}$); (iii) the natural disaster magnitude rate (**Π**); (iv) the economic desgrowth rate (**δ**); (v) and the CC-Surface. The underlying intuition is that the economic impact of climate change depends on a country's vulnerability to temperature change and the floods devastation caused by climate change, which jointly determines the leakage from economic growth and hence the impact on growth. We hope that our model will contribute to a better and deeper understanding of measuring the economic impact of climate change.

A more useful measurement of impact is conducive for appropriate policies, both for dealing with the effects of climate change and also for anticipatory policy measures which seek to lessen the impact of climate change before they occur. For example, underestimating the impact may lead to the government allocating too few resources for addressing the impact of climate change– e.g. public investment in physical infrastructure and income support for households most affected by the climate change. On the other hand, overestimating the impact may cause the allocation of too many resources, raising the risk of inefficiency and waste. By the same token, determining the appropriate level of anticipatory investments to limit the impact of future climate change would benefit from an accurate ex-ante assessment of their impact. The MECC Model can also help in determining the appropriate mix of climate change management and policies. For example, the model may allow policymakers to better estimate and compare the impact of different types of climate change.

The application of our model to two climate change in China – the --- floods of 1931 in Central South China and the Zhangshu and Jiangxi floods in year 2010 – indicates that Zhangshu and Jiangxi floods in 2010 will have a bigger impact than the Central South China floods in 1931. Nevertheless, the immediate implication for Chinese policymakers is that they need to support growth with stronger measures than they implemented in 2010. In particular, they need to provide more fiscal resources for reconstruction efforts to re-build the region’s devastated physical infrastructure which, in turn, will lay the foundation for the recovery of the region’s productive activities, in particular manufacturing. In addition to rebuilding the infrastructure, the government should provide income support for the residents whose homes and livelihoods have been destroyed by possible natural disasters originated from the climate change. While China’s high public debt level constrains the Chinese government’s fiscal space, concerted fiscal support is nevertheless vital for floods China’s recovery.

At a broader level, our results confirm that climate change can have a significant economic impact even in advanced countries with good infrastructure and high level of preparedness. The inescapable policy implication for developing countries, which tend to suffer the bulk of climate change, is that investing in anticipatory measures may yield sizable benefits in the medium and long term even though they can be costly in the short run. Anticipatory measures can reduce the extent of climate change damage, loss of life and disruption to economic activity. Such measures include: (1) Good design and adherence to rigorous building codes; earthquake and storm proofing of buildings; floodplain and drainage designs; hillside stabilization, and other measures related to the natural and manmade environments, (2) Early warning system for floods, storms, epidemics, typhoons, tsunamis, and others. (3) Emergency response plans: evacuation systems; emergency response drills; equipment readiness; supplies storage - e.g. medicine and water. Given the high opportunity costs of using fiscal resources to mitigate the effects of climate change in developing countries, the MECC model’s more accurate measurement of the economic impact of climate change is all the more valuable. Better measurement allows for more efficient and better targeted use of fiscal resources. One interesting direction for future research is to examine the importance of effective communication in mitigating the adverse impact of climate change. It is widely believed that more effective communication by the Chinese government to the general public, for example about the magnitude and nature of the damage, could have limited the damage from the floods. The failure of authorities to quickly and reliably inform the public led to widespread concerns and fear, which further dented consumer and business confidence. Therefore, more and better information is likely to reduce the impact of climate change, and looking at the role of information would contribute to a more accurate measurement of impact.

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TABLES AND FIGURES

Table 1: Major Climate Change Effects on Natural Disasters in Developing Asia, 2000-2012

	Earthquake		**Flood**		**Storm**		**Drought**	
	Deaths	**Damages ($ bill.)**	**Deaths**	**Damages ($ bill.)**	**Deaths**	**Damages ($ bill.)**	**Deaths**	**Damages ($ bill.)**
Central and West Asia	75,000	6	6,000	10	700	2	200	1
East Asia	40,000	131	9,000	67	5,000	73	130	11
Pacific	60	0	60	0	280	0	0	0
South Asia	75,000	7	20,000	20	7,000	3	30	1
Southeast Asia	180,000	13	7,000	6	147,000	9	0	1
Total	370,060	157	42,060	103	159,980	87	360	14

Source: ADB data base.

Table 2: The Calculation of the Climate Change Magnitude Rate (**Π**) & the Economic Desgrowth (**δ**)

Ωt	Ωt-1	√Ωt-1	Ln √Ωt-1	ψL	Φk	**Π**	**δ**
0.00	1	1	0.0000	0.000	0.00	**0.000**	**0.000**
0.01	0.99	0.99	-0.0050	0.001	0.01	**0.000**	**0.000**
0.02	0.98	0.99	-0.0101	0.002	0.02	**0.000**	**0.000**
0.03	0.97	0.98	-0.0152	0.003	0.03	**0.000**	**0.000**
0.04	0.96	0.98	-0.0204	0.004	0.04	**0.000**	**0.000**
0.05	0.95	0.97	-0.0256	0.005	0.05	**0.000**	**0.000**
0.06	0.94	0.97	-0.0309	0.006	0.06	**0.000**	**0.000**
0.07	0.93	0.96	-0.0363	0.007	0.07	**0.000**	**0.000**
0.08	0.92	0.96	-0.0417	0.008	0.08	**0.001**	**0.000**
0.09	0.91	0.95	-0.0472	0.009	0.09	**0.001**	**0.000**
0.10	0.90	0.95	-0.0527	0.010	0.10	**0.001**	**0.000**
.	.	.	.	.	.	**.**	**.**
0.21	0.79	0.89	-0.1179	0.021	0.21	**0.004**	**-0.001**
0.22	0.78	0.88	-0.1242	0.022	0.22	**0.005**	**-0.001**
.	.	.	.	.	.	**.**	**.**
0.30	0.70	0.84	-0.1783	0.030	0.30	**0.009**	**-0.002**
0.31	0.69	0.83	-0.1855	0.031	0.31	**0.010**	**-0.002**
.	.	.	.	.	.	**.**	**.**
0.36	0.64	0.80	-0.2231	0.036	0.36	**0.013**	**-0.003**
0.37	0.63	0.79	-0.2310	0.037	0.37	**0.014**	**-0.003**
.	.	.	.	.	.	**.**	**.**
0.39	0.61	0.78	-0.2471	0.039	0.39	**0.015**	**-0.004**
.	.	.	.	.	.	**.**	**.**
0.42	0.58	0.76	-0.2724	0.042	0.42	**0.018**	**-0.005**
0.43	0.57	0.75	-0.2811	0.043	0.43	**0.018**	**-0.005**
0.44	0.56	0.75	-0.2899	0.044	0.44	**0.019**	**-0.006**
0.45	0.55	0.74	-0.2989	0.045	0.45	**0.020**	**-0.006**
0.46	0.54	0.73	-0.3081	0.046	0.46	**0.021**	**-0.007**
0.47	0.53	0.73	-0.3174	0.047	0.47	**0.022**	**-0.007**
0.48	0.52	0.72	-0.3270	0.048	0.48	**0.023**	**-0.008**
0.49	0.51	0.71	-0.3367	0.049	0.49	**0.024**	**-0.008**
0.50	0.50	0.71	-0.3466	0.050	0.50	**0.025**	**-0.009**
0.51	0.49	0.70	-0.3567	0.051	0.51	**0.026**	**-0.009**
0.52	0.48	0.69	-0.3670	0.052	0.52	**0.027**	**-0.010**
0.53	0.47	0.69	-0.3775	0.053	0.53	**0.028**	**-0.011**
0.54	0.46	0.68	-0.3883	0.054	0.54	**0.029**	**-0.011**
0.55	0.45	0.67	-0.3993	0.055	0.55	**0.030**	**-0.012**
.	.	.	.	.	.	**.**	**.**

0.58	0.42	0.65	-0.4338	0.058	0.58	**0.034**	**-0.015**
0.59	0.41	0.64	-0.4458	0.059	0.59	**0.035**	**-0.016**
0.60	0.40	0.63	-0.4581	0.06	0.60	**0.036**	**-0.016**
0.61	0.39	0.62	-0.4708	0.061	0.61	**0.037**	**-0.018**
.	.	.	.	.	.	.	.
0.63	0.37	0.61	-0.4971	0.063	0.63	**0.040**	**-0.020**
0.64	0.36	0.60	-0.5108	0.064	0.64	**0.041**	**-0.021**
0.65	0.35	0.59	-0.5249	0.065	0.65	**0.042**	**-0.022**
.	.	.	.	.	.	.	.
0.68	0.32	0.57	-0.5697	0.068	0.68	**0.046**	**-0.026**
0.69	0.31	0.56	-0.5856	0.069	0.69	**0.048**	**-0.028**
0.70	0.30	0.55	-0.6020	0.070	0.700	**0.049**	**-0.029**
0.71	0.29	0.54	-0.6189	0.071	0.71	**0.050**	**-0.031**
0.72	0.28	0.53	-0.6365	0.072	0.72	**0.052**	**-0.033**
0.73	0.27	0.52	-0.6547	0.073	0.73	**0.053**	**-0.035**
0.74	0.26	0.51	-0.6735	0.074	0.74	**0.055**	**-0.037**
0.75	0.25	0.50	-0.6931	0.075	0.75	**0.056**	**-0.039**
0.76	0.24	0.49	-0.7136	0.076	0.76	**0.058**	**-0.041**
0.77	0.23	0.48	-0.7348	0.077	0.77	**0.059**	**-0.044**
0.78	0.22	0.47	-0.7571	0.078	0.78	**0.061**	**-0.046**
0.79	0.21	0.46	-0.7803	0.079	0.79	**0.062**	**-0.049**
.	.	.	.	.	.	.	.
0.83	0.17	0.41	-0.8860	0.083	0.83	**0.069**	**-0.061**
0.84	0.16	0.40	-0.9163	0.084	0.84	**0.071**	**-0.065**
0.85	0.15	0.39	-0.9486	0.085	0.85	**0.072**	**-0.069**
0.86	0.14	0.37	-0.9831	0.086	0.86	**0.074**	**-0.073**
0.87	0.13	0.36	-1.0201	0.087	0.87	**0.076**	**-0.077**
0.88	0.12	0.35	-1.0601	0.088	0.88	**0.077**	**-0.082**
0.89	0.11	0.33	-1.1036	0.089	0.89	**0.079**	**-0.087**
0.90	0.10	0.32	-1.1513	0.090	0.90	**0.081**	**-0.093**
0.91	0.09	0.30	-1.2040	0.091	0.91	**0.083**	**-0.100**
0.92	0.08	0.28	-1.2629	0.092	0.92	**0.085**	**-0.107**
0.93	0.07	0.26	-1.3296	0.093	0.93	**0.086**	**-0.115**
0.94	0.06	0.24	-1.4067	0.094	0.94	**0.088**	**-0.124**
0.95	0.05	0.22	-1.4979	0.095	0.95	**0.090**	**-0.135**
0.96	0.04	0.20	-1.6094	0.096	0.96	**0.092**	**-0.148**
0.97	0.03	0.17	-1.7533	0.097	0.97	**0.094**	**-0.165**
0.98	0.02	0.14	-1.9560	0.098	0.98	**0.096**	**-0.188**
0.99	0.01	0.10	-2.3026	0.099	0.99	**0.098**	**-0.226**

Source: MECC Model Simulations

Table 3: The Climate Change Growth Rates (αi) and National Climate Change Vulnerability Rate (ΩT)

No.	Country	α1	α2	α3	α4	α5	α6	α7	α8	α9	α10	α11	α12	α13	α14	α15	α16	ΩT
1	China	0.95	0.35	0.99	0.75	0.15	0.99	0.35	0.25	0.3	0	0.25	0.95	0.25	0.1	1	0.95	0.54
2	U.S.	0.95	0.25	0.85	0.35	0.55	0.85	0.2	0.2	0.7	0.25	0.3	0	0.75	0.4	0.15	0.95	0.48
3	Australia	0.35	0.35	0.6	0.5	0	0.5	0.2	0.2	0	0	0.45	0.1	0.25	0	0.65	0.35	0.28
4	Taiwan	0.8	0.25	0.65	0.55	0	0.4	0.5	0.35	0	0	0.25	0.99	0.99	0	0	0.99	0.42
5	Chile	0.85	0.25	0.45	0.55	0.25	0.99	0.15	0.25	0.3	0.35	0.3	0	0.1	0.1	0	0	0.31
6	Guatemala	0.95	0.15	0.45	0.3	0	0.35	0.1	0	0	0.75	0.1	0.35	0.15	0	0	0.25	0.24
7	Panama	0.95	0.15	0.35	0.35	0	0.25	0.1	0	0	0.75	0.1	0.35	0.3	0	0	0.65	0.27
8	Mexico	0.95	0.20	0.59	0.45	0	0.99	0.1	0.15	0	0.6	0.1	0.45	0.25	0	0.05	0.35	0.33
9	Russia	0.95	0.15	0.75	0.55	0.9	0.35	0.15	0.25	0.95	0	0.5	0	0	0.99	0	0	0.41
10	Singapore	0.35	0.15	0.25	0.1	0	0.15	0.2	0.2	0	0	0	0.4	0.2	0	0	0.1	0.13
11	Malaysia	0.35	0.05	0.35	0.2	0	0.2	0.1	0.1	0	0	0.05	0.25	0.15	0	0	0.15	0.12
12	Brazil	0.55	0.25	0.25	0.4	0	0.25	0	0.05	0	0	0.25	0.15	0.25	0	0	0.15	0.16
13	New Zealand	0.95	0.15	0.25	0.35	0.25	0	0.1	0.05	0	0	0.3	0	0	0.1	0	0	0.16
14	Iceland	0.65	0.20	0.11	0.25	0.6	0	0.15	0.2	0.95	0	0.8	0	0	0.85	0	0	0.30
15	Israel	0.85	0.15	0.21	0	0	0.1	0	0	0	0	0.1	0	0	0	0	0	0.09
16	Spain	0.75	0.10	0.35	0	0	0.2	0	0.05	0	0.1	0.05	0	0	0	0	0	0.10
17	Bangladesh	0.9	0.2	1	1	0	0.4	0.35	0.3	0.25	0	0.05	1	0.7	0	0	0.6	0.42
	TOTAL	**0.82**	**0.21**	**0.53**	**0.42**	**0.17**	**0.44**	**0.17**	**0.16**	**0.22**	**0.18**	**0.25**	**0.31**	**0.27**	**0.16**	**0.12**	**0.34**	0.30

Ω_i = The climate change growth rates

α1	Mean temperature	**α4**	Precipitation extremes	**α7**	Ocean acidification	**α10**	Monsoons
α2	Temperature extremes	**α5**	Snow and ice	**α8**	Sea level	**α11**	Sea level pressure
α3	Mean precipitation	**α6**	Carbon cycle	**α9**	El Niño	**α12**	Radiative forcing

	High level of risk		
		α13	Tropical cyclones
1	Mean temperature	**α14**	Hailstorms
2	Mean precipitation	**α15**	Sandstorm
3	Carbon cycle	**α16**	Hurricanes and typhoons

Source: Intergovernmental Panel on Climate Change –IPCC-

TABLE 4: GNP Growth Rates from China (1931 and 2010)

1	1931	3% 1.49%	**δ = -1.51**	**Ω_T = 0.95**	**Π = -5**
2	2010	13.1 10.3%	**δ = -2.80**	**Ω_T = 0.99**	**Π = -11**

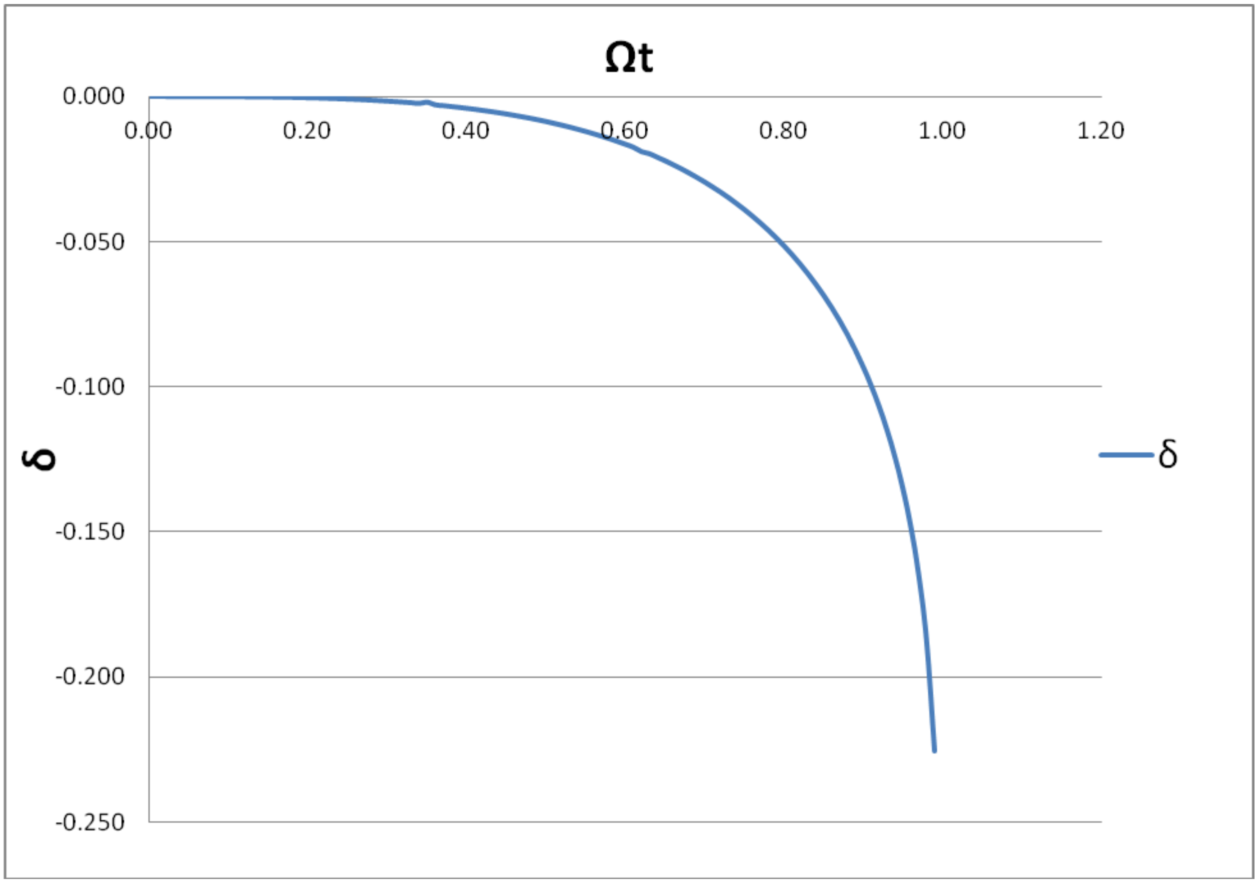
Variables:

δ = GNP Desgrowth Rate
ΩT = The National Climate Change Vulnerability Rate

Π = The Climate Change Magnitude Rate

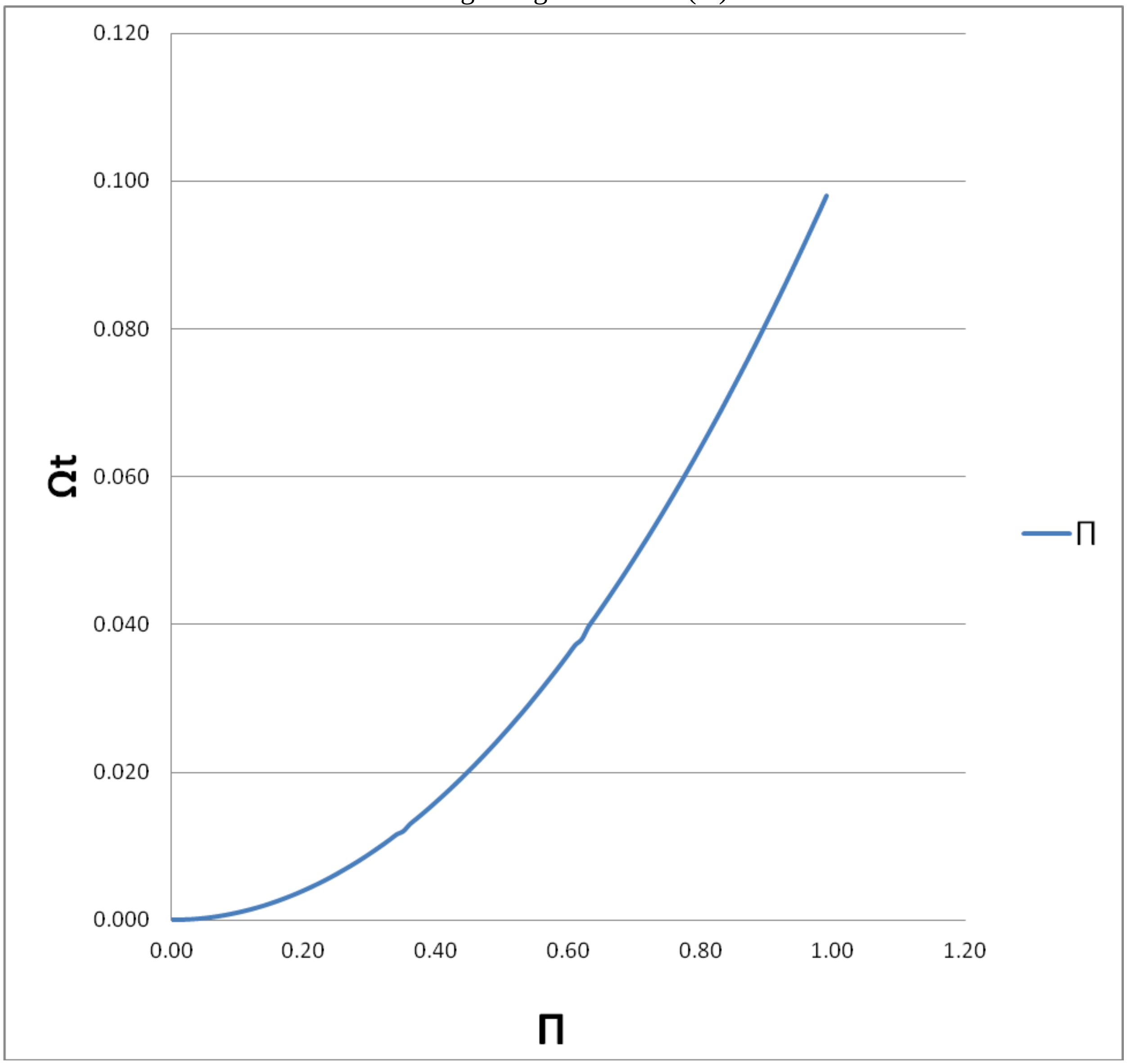
Source: International Monetary Fund (IMF) and National Bureau of Statistics of China

Figure 1: The Relationship between the National Climate Change Vulnerability Rate (**Ωt**) and the Economic Desgrowth (**δ**)



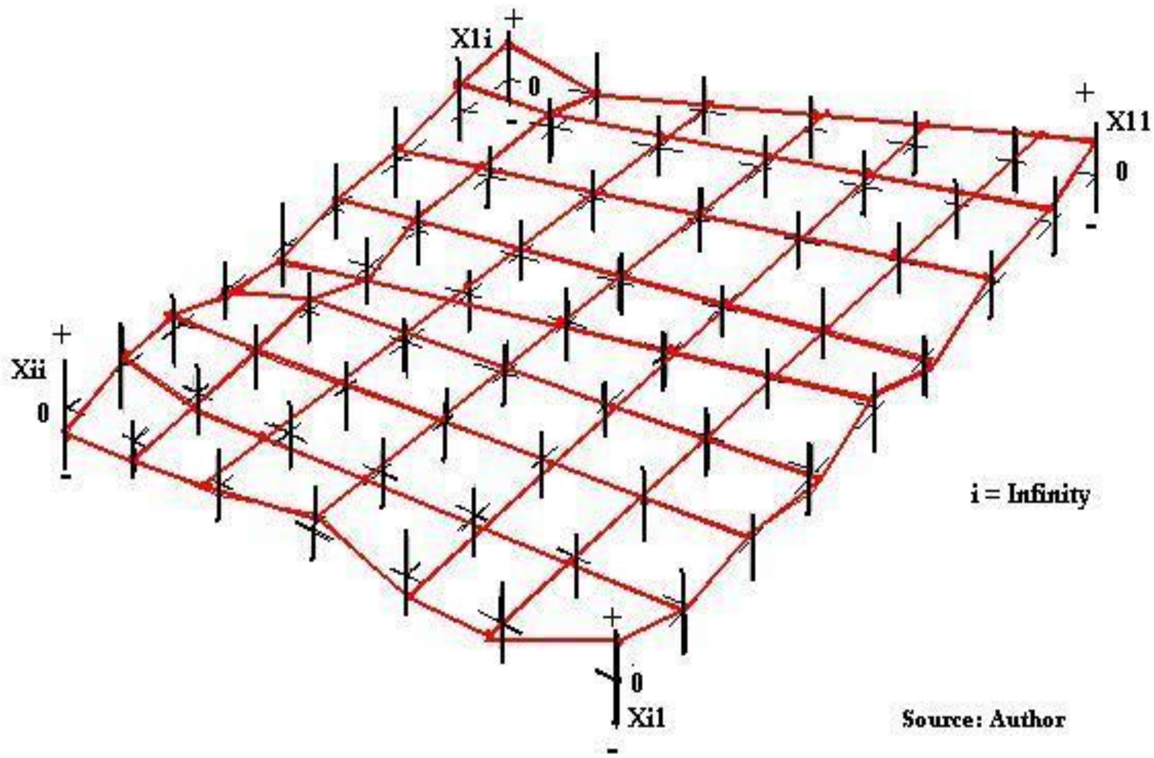
Source: See Table 2

Figure 2: How the National Climate Change Vulnerability Rate (Ω_T) can affect on The Climate Change Magnitude Rate (**Π**)



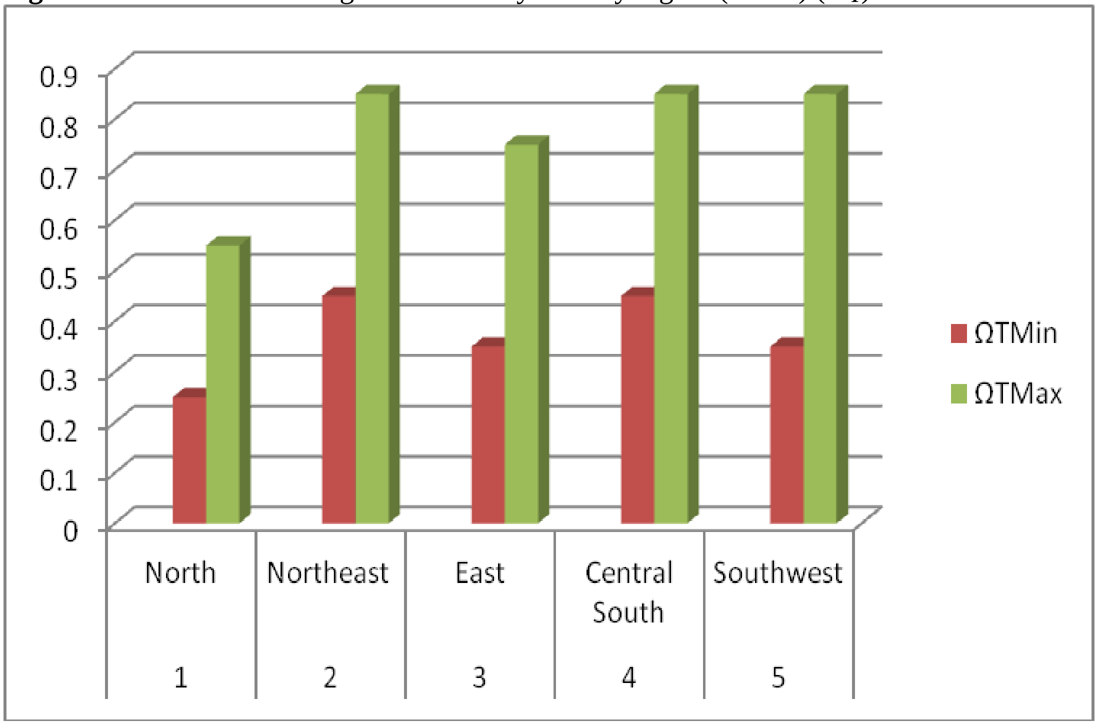
Source: See Table 2

Figure 3: The Mega-Surface Coordinate Space



Source: Author

Figure 4: The Climate Change Vulnerability Rate by region (China) (Ω_T)

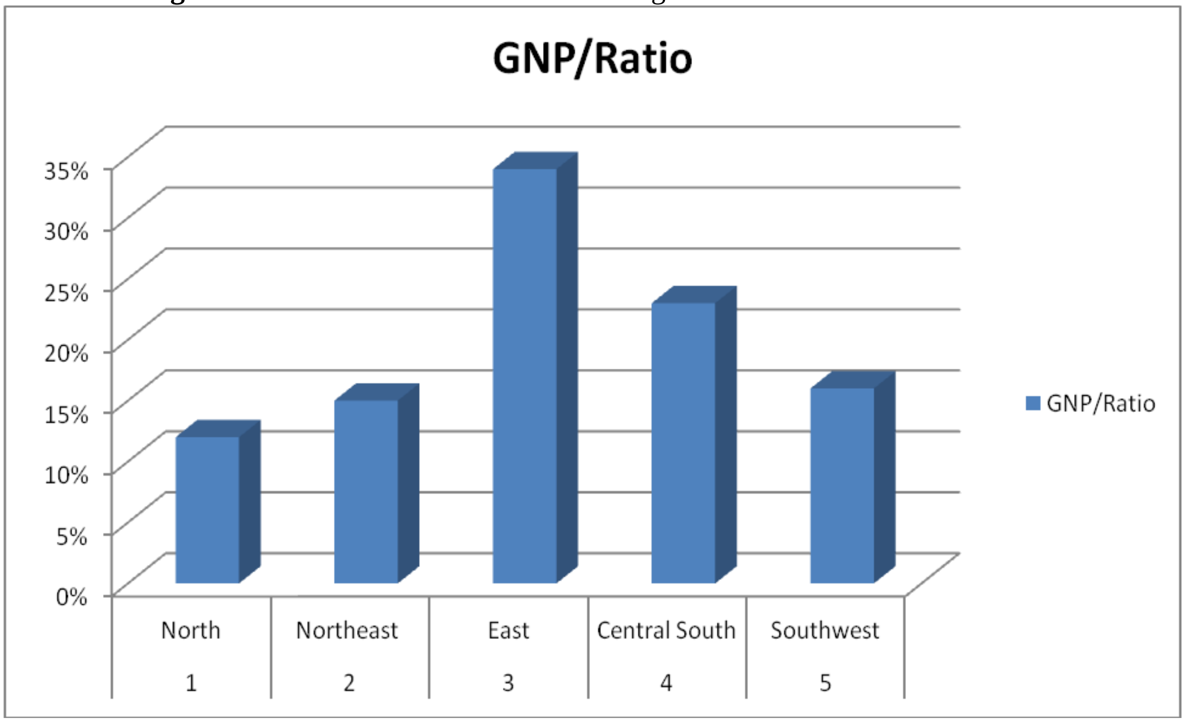


Source: MECC Model.

Region		$\boldsymbol{\Omega_{TMin}}$	$\boldsymbol{\Omega_{TMax}}$
1	North	0.25	0.55
2	Northeast	0.45	0.85
3	East	0.35	0.75
4	Central South	0.45	0.85
5	Southwest	0.35	0.85

North: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia.
Northeast: Liaoning, Jilin, Heilongjiang
East: Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong
Central South: Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan
Southwest: Chongqing, Sichuan, Guizhou, Yunnan, Tibet

Figure 5: Contribution of each Chinese Region on the Final GNP Ratio

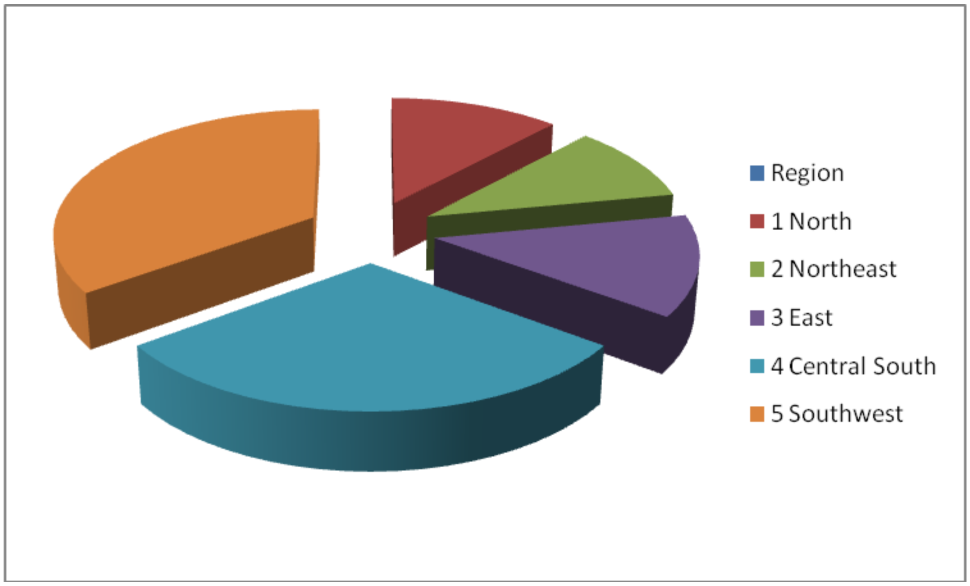


Region		GNP/Ratio
1	North	12%
2	Northeast	15%
3	East	34%
4	Central South	23%
5	Southwest	16%

Source: World Bank and National Bureau of Statistics of China.

North: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia.
Northeast: Liaoning, Jilin, Heilongjiang
East: Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong
Central South: Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan
Southwest: Chongqing, Sichuan, Guizhou, Yunnan, Tibet

Figure 6: Concentration of Agriculture Production at China

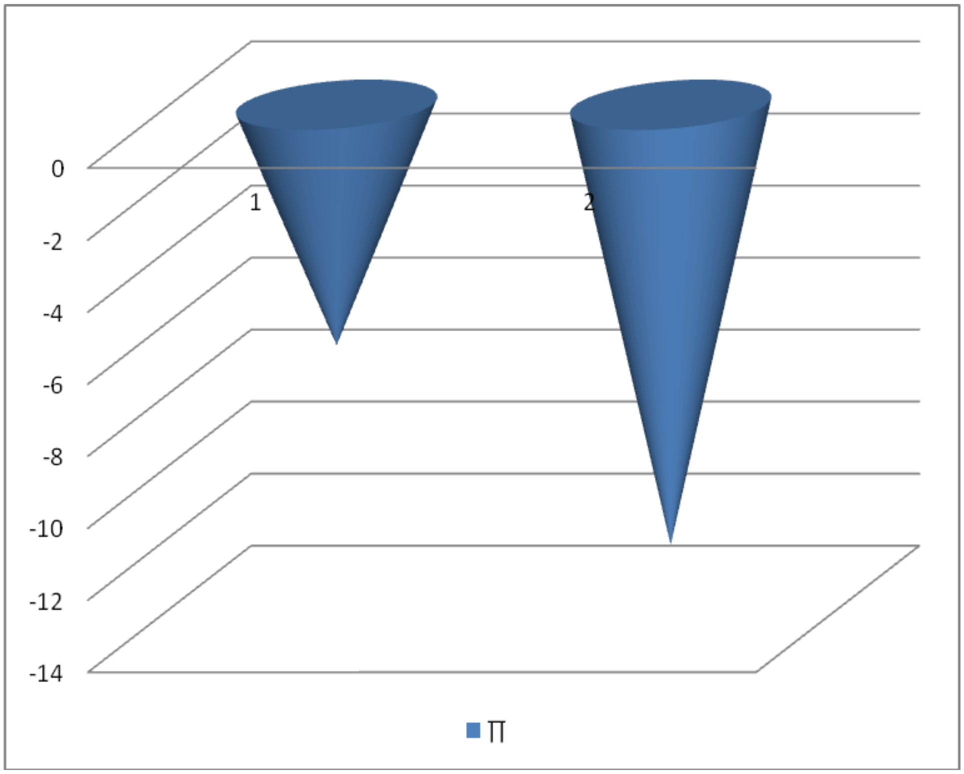


Region		**Concentration**
1	North	12%
2	Northeast	10%
3	East	13%
4	Central South	30%
5	Southwest	35%
	Total	100%

Source: FAO and Ministry of Land and Natural Resources of China.

North: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia.
Northeast: Liaoning, Jilin, Heilongjiang
East: Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong
Central South: Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan
Southwest: Chongqing, Sichuan, Guizhou, Yunnan, Tibet

Figure 7: Climate Change Magnitude Rate (Π) between China floods 1931 and 2010

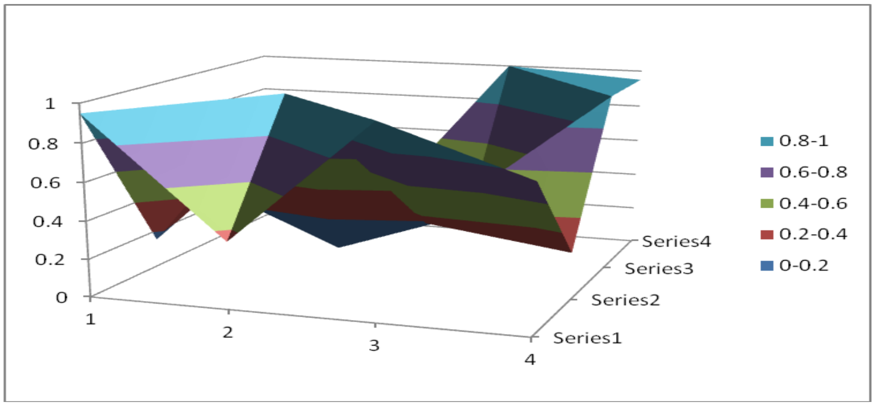


Source: See Table 2

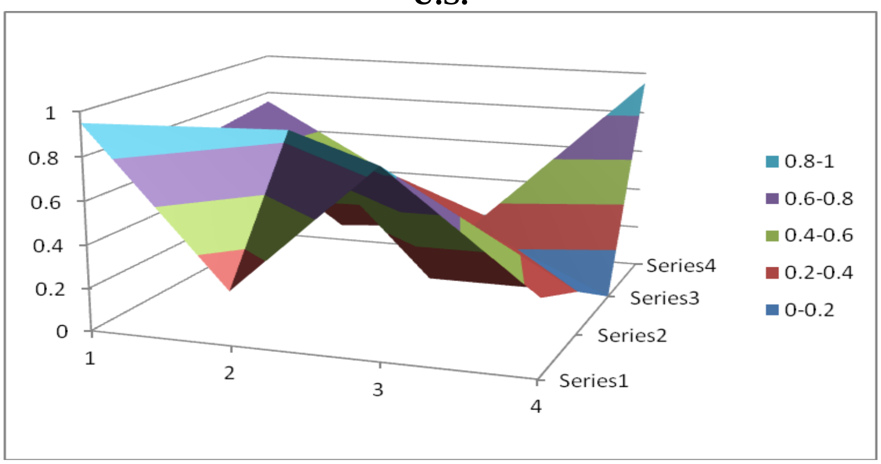
Note: Final results from MECC Model

Figure 8: CC-Surface: China, U.S., Malaysia, Guatemala, Bangladesh

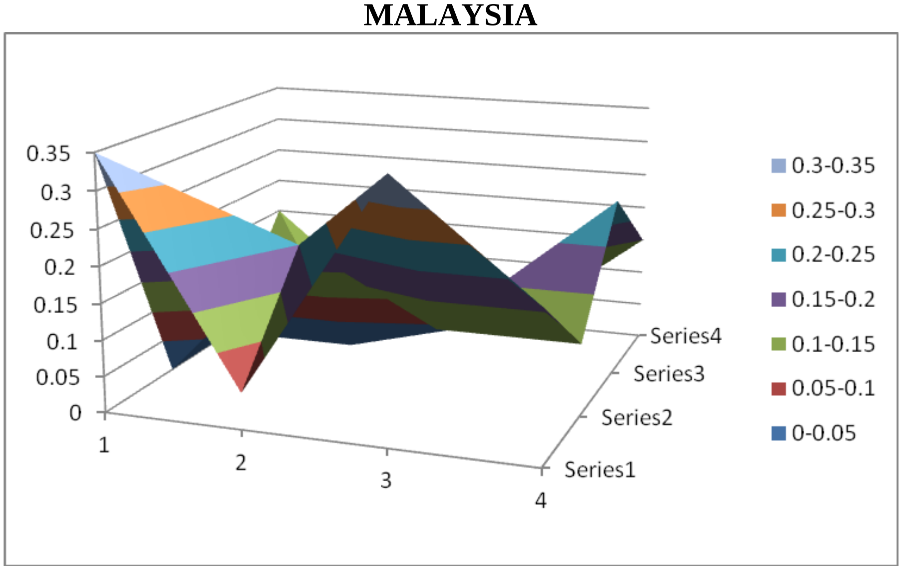
CHINA



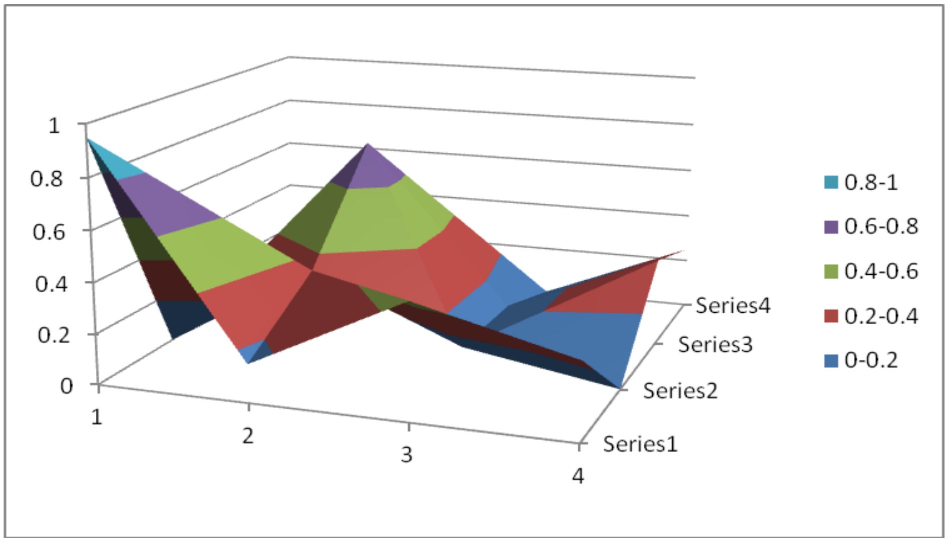
U.S.



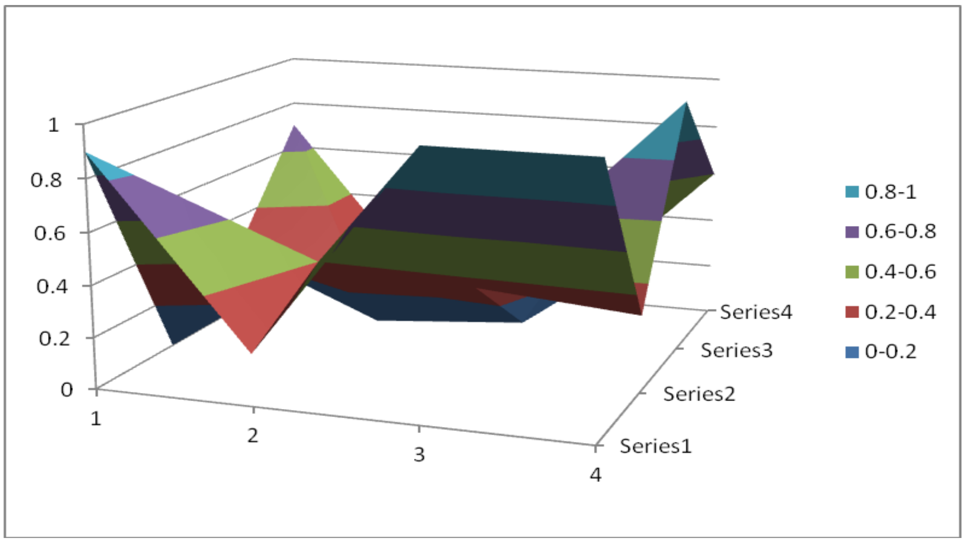
MALAYSIA



GUATEMALA



BANGLADESH



Source: Intergovernmental Panel on Climate Change –IPCC- data and MECC Model results
Note: See Table 3.